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Tracing Teachers' Use of Technology in a Laptop Computer School: The Interplay of Teacher Beliefs, Social Dynamics, and Institutional Culture

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Research on ubiquitous computing in schools has documented that teachers often change instructional practices over time when using technology with students and has further suggested that teachers' use of technology may play a role in their shifting toward more constructivist pedagogy. Our two-year study takes an ethnographic perspective in examining how three middle school teachers learned to use technology in the context of a laptop computer program. The ways in which those teachers eventually integrated computers into classroom instruction were powerfully mediated by their interrelated belief systems about learners in their school, about what constituted "good teaching" in the context of the institutional culture, and about the role of technology in students' lives. The condition of ubiquitous technology did not initiate teachers' movement toward constructivist instruction. Rather, the laptops were a catalyst that enabled one participant, who had a pre-existing dissatisfaction with teacher-centered practices, to transform her classroom through collaborative student work and project-based learning.

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More than a thousand schools nationwide have committed themselves to some form of laptop computer initiative, and the number is increasing

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rapidly. In New York City, for instance, the school board recently considered a plan that would provide laptop computers for every fourth-grader in the system. The governor of Maine proposed in early 2000 that his legislature approve the purchase of laptop computers for every seventh-grader in the state (Zehr, 2000). These programs are one of the fastest-spreading phenomena in American schooling today. They have the potential to change, for better or worse, significant aspects of teaching and learning.

Laptop computer programs introduce a host of complex issues into a school community, not the least of which is how teachers will adapt to classroom settings in which every student owns a mobile suite of powerful technological tools and has telecommunications access to a global repository of information and ideas. Laptop learning environments are arguably unique contexts in which to study how teachers integrate technology into their working lives and into the curriculum.

Much of the literature on how teachers come to use technology in such programs, however, remains anecdotal and undertheorized. By contrast, the broader research base on teachers' use of desktop computers in classrooms is better established and has documented that *teachers can and do change* their instructional practices when using technology (Baker, Herman, & Gearhart, 1996; Sandholtz, Ringstaff, & Dwyer, 1997). In particular, several studies suggest that teachers who use technology tend to become more constructivist in their pedagogical orientation over time (Becker & Ravitz, 1999; Means, 1994; Mehlinger, 1996), but even that literature has not offered clear explanations for how or why some teachers transform their practice.

Part of the reason for the lack of explanatory power in this research base is that the majority of studies have been devoted to tracing changes in individual teachers' knowledge, beliefs, and instructional practices, while ignoring the fact that teachers' thinking is often influenced by both the social contexts in which they operate and the institutional cultures that profoundly shape the meaning of their work (Little, 1990; Minick, 1985). Past studies of how teachers use technology have noted the importance of various contextual factors such as the characteristics of staff development experiences, access to technology, availability of support, and opportunity to interact with colleagues. These factors, however, are often treated as independent variables whose effects contribute in various magnitudes to the behavior of individuals. Recent scholarship on teacher learning has shifted the focus from teachers as isolated individuals to the groups and communities in which teachers participate (Stein & Brown, 1997). Teachers' thinking, in this view, is social in nature and distributed across individuals (Putnam & Borko, 2000). Attention is redirected from the individual to the various groups and settings in which learning occurs (Lave & Wenger, 1991; Rogoff, 1994); instead of being located in the cognitive structures and mental representations of individual teachers, learning becomes situated in the "fields of interaction" among individuals (Hanks, 1991).

Furthermore, this perspective of teacher learning as socially situated and distributed is linked with the assumption that learning takes place in specific contexts whose social structures have been developed under historically and

culturally grounded conditions. Schools, as institutional cultures, are infused with notions of ideal futures for students and teachers, and those prospects are promoted through the ways in which school activities are structured (Grossman, Smagorinsky, & Valencia, 1999). Students and teachers aspire to culturally defined futures that motivate their activity and the ways in which they mediate one another's progress toward those goals (Joseph, Bravmann, Windschitl, Mikel, & Green, 2000).

In attempting to understand teacher learning in technology-rich environments, these sociocentric perspectives (Soltis, 1981) draw upon both sociocultural (Wertsch, 1994) and situative (Greeno, 1997) theory to take into account teachers' experiences that either have been ignored or remain invisible when examined through the lens of individual cognition—experiences such as constructing knowledge about technology and the curriculum *with* peers and students, making sense of the use of technology by coordinating one's beliefs about teaching and learning with the expectations of the institutional culture, and participating in formal and informal activity settings in which one can learn about technology. Because these theoretical perspectives recognize (a) the construction of knowledge among teachers and students, (b) the cultural contexts that mediate expectations for teaching and learning, and (c) the range of learning settings in which teachers participate, they are more likely to move us beyond *what* teachers learn and help us understand *how* and *why* teachers come to use technology in different ways over time. This study traces the activities of three teachers as they construct, with peers, a range of uses for laptop computers in the classroom and reconcile those decisions within the context of their institutional culture.

Background

Teacher Learning in Technology-Rich School Settings

Researchers have only recently invested themselves in serious study of how teachers come to use technology in their classrooms and what kinds of influences shape their thinking (Kerr, 1996). Much of what we know about teacher learning in technology-rich settings comes from the Apple Classrooms of Tomorrow (ACOT) project, about which data have been accumulating since 1985. The ACOT project equipped a single classroom in each of five schools with software, printers, laser disc players, and desktop computers—one for each student and teacher in the classroom and one additional computer for each student and teacher for home use. Researchers associated with the ACOT project made long-term observations of teachers learning to use technology and postulated five stages of technology integration by teachers (Sandholtz, Ringstaff, & Dwyer, 1997). These stages range from *entry*, in which teachers are not yet comfortable with computers and choose not to use them, to *invention*, in which teachers are capable of creating fundamentally different learning environments in their classrooms through the use of technology.

Stage theories may be useful as a heuristic device for teachers to critically examine the levels of technology integration in their own classrooms,

but for researchers the idea of stages as a linear, universal path that all (or most) teachers follow is problematic on several levels. In the ACOT studies, for example, it is not clear whether the stages were derived from the long-term observations of individual teachers or represented levels that different teachers occupied at one point in time. If the latter is true, then we must assume that individual teachers would progress from less- to more-advanced stages over time. Also, because this particular stage theory posits novice users of technology as teacher-centered and describes how those individuals eventually used technology for collaborative, student-centered teaching only in later stages, it apparently precludes from the model teachers who are initially student-centered in their instructional approaches or who already have moderate technological expertise. Even if one accepts the proposition that stages as developmental entities exist and that teachers move from one stage to the next, it remains unclear *how* individuals make leaps of progress and whether they do so by observing others teach, accruing expertise with technology, acting on individual insight, experiencing epistemological shifts that underlie pedagogy, or responding to some as-yet undefined influences.

Other researchers who investigated the ACOT classrooms found considerable variation in the instructional uses of technology, proposing that "teachers' content and pedagogical knowledge . . . provide key explanatory variables underlying our uneven findings" (Baker, Herman, & Gearhart, 1996, p. 196). The original ACOT researchers, on the other hand, held that teacher beliefs about learning and about student and teacher roles in the classroom were the prime influence on how teachers used the technology (Sandholtz, Ringstaff, & Dwyer, 1997). They found that teachers alternated between instructional approaches that had worked for years and new approaches that seemed more appropriate in their technology-rich classrooms—vacillations that the researchers suggested were caused by dilemmas stemming from long-held beliefs about teaching rather than from problems inherent in learning to use technology.

More recent large-scale statistical studies of computer-using teachers have moved beyond the notion of practitioners as isolated learners and suggest that teacher learning and instructional innovation thrive in environments where there are others who are experimenting with technology. For example, in a national survey of 516 teachers of Grades 3 through 12, Becker (1994) found that of 51 separate teacher-environment variables, the one that exhibited the largest difference between exemplary computer-using teachers and other computer-using teachers was simply the total number of teachers at their schools who used computers. Becker suggests that teachers "must have access to other people from whom they can learn, either experts who have already mastered the resource or a community of teacher-learners who pool their efforts and share their exploratory findings" (p. 303).

In addition to the assumptions about teacher beliefs and social or professional interactions as catalysts for the transformation of teaching with technology, some researchers have suggested that under certain conditions, teachers' use of technology stimulates movement toward constructivist ped-

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agogy. In a study of 153 schools where social support networks for teachers and sufficient technological infrastructures were in place, Becker and Ravitz (1999) found that teachers' increased use of constructivist teaching practices¹ was related to their sustained use of computers and their pedagogical exploitation of the Internet; Becker and Ravitz claim that the supportive conditions and the use of technology may cultivate pedagogical beliefs that underlie constructivist practices. In particular, they found that frequent computer and Internet use appear to be related to teachers' (a) being more willing to discuss a subject about which they lack expertise and allowing themselves to be taught by students; (b) organizing multiple, simultaneous activities during class time; (c) assigning complex projects for students; (d) giving students greater choice in learning tasks; and (e) recognizing the initiative that students can take outside class to do high-quality work. Becker and Ravitz infer from their data that:

the relationship between technology use and pedagogical change is truly causal and not the mere conjunction of innovative teachers who happen to both use technology and develop a more constructivist pedagogy. However, this [work] still leaves unanswered the question of whether the causal impact is limited to teachers who were already inclined to teach in a constructivist manner and simply needed the appropriate resources to do so, or whether the experience of using computers or the Internet in a substantial way with students itself leads otherwise "non-constructivist" teachers to rethink their pedagogical priorities and philosophies of teaching. (p. 381)

Others have similarly stated that technology "encourages" student-centered cooperative learning (Baker, Herman, & Gearhart, 1996; Mehlinger, 1996) and that technology implementation "inspires" teachers to use more complex tasks and materials in instruction (Means, 1994). In a two-year study of computers and classroom culture at one high school, Schofield (1995) found that, as teachers began to use computers with their students, some began to shift their instructional roles. Their classrooms became less teacher-centered and the teachers began to see themselves as facilitators of learning rather than as authority figures whose job it was to impart knowledge.

In summary, current research indicates that, in conjunction with the use of technology over time, teachers often change their classroom practices, and some adopt more student-centered pedagogical approaches. Our understanding of how and under what specific conditions these transformations take place is less clear and may require more highly contextualized investigations of teachers who learn to use technology with colleagues and students.

Laptop Computer Programs as Unique Contexts for Teacher Learning

One of the basic assumptions of this study is that, in contrast to the more conventional presence of desktop technology in schools, laptop programs² create novel circumstances within classrooms and introduce special features into the broader institutional landscape that distinguish those environments

from others in which there is pervasive desktop technology. This assumption has two threads of logic: The first deals with the affordances of the laptop as a tool for learning; the second, with broader programmatic issues accompanying the introduction of laptops into schools that involve curricular, administrative, fiscal, and even cultural concerns.

With regard to the technology itself, laptops are portable; in a school setting they can be carried from class to class, used on top of a desk, transported around the room, or placed out of sight; they can be stolen, dropped, shared, customized, or confiscated. At a moment's notice a student can pull the computer from her backpack, lift the cover, and make the tool part of the classroom environment. Because students can own their laptops, they are often used as personal repositories for storing information and as tools for organizing students' daily schedules. Portability combined with ownership means that students will have the same set of tools and products of work available to them throughout the school day, as well as at home.

In most respects, laptops are orders of magnitude beyond the computers used in previous studies of technology-rich schools (considering factors such as processing speed, graphics display, video/audio capabilities, network connectivity, etc.). Portable computing has also emerged roughly in coincidence with the rise of the World Wide Web and the widespread use of e-mail. These telecommunications functions, combined with the greater processing power of the laptops, allow young learners to take virtual tours of art galleries, track weather around the world in real time, follow the passage of a bill through Congress, or become part of a research community with students from other schools (Windschitl & Irby, 1999).

In laptop classrooms, teachers must consider how to execute curriculum and manage an environment in which learners can pick up their computers to sit with others who are working on similar problems, bring the computer to the teacher with a question, or connect with learners outside the classroom. If permitted, students have access to new flexibility in approaching their work and organizing themselves to do the work. Not only is the teacher decentered as the focus of classroom activity, but the classroom itself can be reconfigured by portable technology; "places and spaces" for learning can become more fluid with laptops.

Other ways in which portable computing creates a novel context for teaching and learning have to do not with the technology itself but with the opportunities and tensions associated with programs that usher laptops into a school. The introduction of laptops is often preceded by some community dialogue among teachers, parents, and administrators about the role of technology in schooling. The various educational stakeholders in these conversations have special concerns. Teachers wonder how they will adapt to the presence of new tools and what kind of support they will receive to learn to use them. Principals contemplate the administration of such programs and must consider changes in teaching assignments, in-service schedules, and the school's technology infrastructure. School board members may deliberate on how technology will help the school achieve its mission. And parents, some of whom may

have only a passing interest in school decisions, can find themselves passionately involved in deliberations about adopting a laptop program. In many cases, parents must consider the implications for their children of being intimately connected to an instrument of high technology, and they often are expected to commit themselves to the purchase of the still-expensive technology.

Context of Study

This investigation is a multi-case study of three teachers at Woodvale Middle School, an institution that had recently initiated a laptop program in which each student was required to purchase a portable computer and each teacher was furnished with a portable computer. Woodvale is a co-educational Catholic independent school located in an urban-suburban neighborhood in a large city in the American Northwest. The school is guided by the philosophy of its founder, the missionary nun Mother Cabrini, who placed equal emphases on "educating hearts and minds." Woodvale is divided into a lower school (Grades K-5) and a middle school (Grades 6-8). Approximately 150 students are enrolled in the middle school, and about half are Catholic. A school policy caps class size at 14 students for kindergarten and 18 students for Grades 1-8. The school attracts students who are highly motivated with average or above-average academic ability. The faculty is experienced and well educated.

The typical student family is affluent, and parents expect an academic program for their children that is rigorous enough to prepare them for entrance into private high schools and universities. Parents regularly contact the teachers by telephone or e-mail about their children's work. As a result, the majority of the faculty feel significant pressure to satisfy the implicit and often explicit expectations of parents by maintaining high academic standards and being attentive to all forms of communication from home. Despite these pressures, teachers claim they receive support from most parents and frequently use the metaphor of "family" when they describe the atmosphere of the school community.

The seeds for Woodvale's laptop program were sown when a parent member of the school's technology committee suggested that the faculty explore the possibility of participating in a laptop program. One school administrator and one faculty member subsequently conducted an investigative trip to a national educators' conference on laptops and returned from it convinced that a laptop program was worth pursuing. Encouraged by a general belief in the inevitability of portable computing in schools and by a desire to be on the cutting edge of educational technology, board members approved a plan to require all middle school students to own laptop computers beginning with the 1998 school year. The board allocated resources for infrastructure (computer servers, wiring, etc.) and created a new administrative position: the Director of Technology would manage the laptop program and all aspects of the school's information services.

One year before the program's implementation, the teachers received their own laptop computers and attended technology workshops. The school

also planned to purchase wireless modems for use in classrooms, but the plan was scaled back because of budgetary concerns and acceptable Internet use issues. As an alternative, each teacher received eight wireless modems for classroom use. That arrangement was adequate but not one that teachers had expected.

During this period, in-services and technology-based discussions were common; faculty meetings began to feature brief highlights of new types of software as well as discussions of how technology might be integrated into various subjects. The following year (referred to as Year 1 of this study), all sixth- and seventh-grade students had purchased laptop computers, and the talk about technology figured even more prominently at faculty meetings. The Director of Technology was in charge of the first 20 minutes of each meeting and made a regular practice of having various teachers present to peers new ways in which they were implementing computers into instruction.

Halfway into the first year of the laptop program, the Director of Technology had a series of disagreements with the Head of School about the use of technology in the lower elementary grades and left the school. The school immediately hired a new technical support staff member but did not classify the position as administrative. Individual teachers took responsibility for the "new applications of technology" presentations at faculty meetings, but that practice grew less frequent. Although the administration had only vague plans for the schoolwide use of the laptops, technology remained a regular topic at faculty meetings. Teachers were still provided with workshops in technology use, and many were funded to travel to laptop conferences.

Research Questions

Before we defined specific boundaries for the study, broad areas of investigation were identified with the understanding that they would serve as guidelines for collecting data about the school community and that research questions, along with their data collection strategies, would be developed over time. After several months, two questions emerged that we felt captured the complexity of how the teachers were learning to use laptop technology in their classrooms:

1. How do participants' personal histories and beliefs about learners and learning play out within the institutional culture to influence their technology-related instructional practices?
2. How do teachers construct technology-related norms and practices with peers and students through their participation in various activity settings?

In the process of answering these questions, we also indexed the evolving instructional strategies of these teachers against a normative trajectory of technology use described in the literature (i.e., moving from traditional to constructivist teaching practices). Thus a third question emerged:

3. Does the condition of ubiquitous computing influence teachers' movement toward constructivist pedagogy?

Methods

Methodological Orientation

To investigate our research questions we employed a multi-case study approach using an ethnographic perspective (see Gee & Green, 1998; Hymes, 1982). An *ethnographic perspective*, as opposed to a complete ethnography, does not focus on understanding an entire culture but rather can be used to take a more focused look at the actions of members of a group—examining “bits of life” (Bloome, 1989; Hymes, 1982). This approach is well suited to practice-oriented theories of cultural activity (Ortner, 1984) with a concern for understanding culture as constituted in and through the everyday practices of members of a social group (Green, Dixon, & Zaharlick, in press). The ethnographic approach to investigating sociocultural practices is useful in revealing principles of practice that are constructed by members as they fit into roles and relationships, establish norms and expectations, and negotiate rights and obligations that constitute membership in the local group. In particular, this approach helped us understand how differential access to the ideas of others within a group shaped opportunities for learning.

We began the study with a “grand tour” of the school community to identify potential participants and find out with whom they interacted and when, where, under what conditions, and with what outcomes (Spradley, 1980; Spradley & McCurdy, 1972). We visited classes, ate lunch with the teachers, attended faculty meetings and school board meetings, participated in hallway conversations and teachers' workshops, and traveled to regional technology conferences with teachers. This initial phase of data collection set the stage for a more focused examination of particular cultural practices, events, and processes. We used prior research about teachers and technology to guide the initial problem formulation (Spindler & Spindler, 1987). The second phase of data collection was guided by what members of the group indicated through their actions were “culturally marked” or significant to examine. In response to accumulating data, we made ongoing decisions about what types of questions to ask participants (and ourselves) and how we could conduct a meaningful analysis of that data.

Selection of Cases/Participants

This study extended from the beginning of the 1998–1999 school year (Year 1) through the 1999–2000 school year (Year 2) and three months into the 2000–2001 school year. The idea for the study originated when one of the teachers at Woodvale enrolled in a university course on using computers in classrooms (taught by Mark Windschitl in the summer of 1998) and mentioned the proposed laptop program at her school. After exploratory conversations with the Head of School and several teachers, we found that

they were willing to participate in a study of their technology practices. We established a "social contract" with the faculty by explaining what our intentions were in studying the site and how we would maintain privacy and respect for their work.

After reviewing early interview and observation data, we identified two teachers as likely to provide illuminating as well as contrasting cases—Carol and Stephan. During the first year of the program, Carol had begun to explore more student-centered instruction using technology in her social studies classroom. Stephan was using the technology as a personal productivity tool but expressed reservations about the use of the laptops in his mathematics classroom. In the summer between the first and second years of the study, a new teacher, Julia, was also asked to be a participant. Her initial ideas about instruction and technology were more conservative than Carol's or Stephan's, and we felt that she would be an informative case to follow.

Data Collection

Data collection during the first few months of this two-year project was aimed at identifying important norms and practices of the school community. We took field notes at several faculty meetings and three school board meetings. We also observed each of the eleven teachers in the middle school at least twice; we took field notes and later interviewed them about their classroom practice. The first set of interviews was designed to elicit beliefs about teaching and learning. The second set focused more on teachers' instructional planning and uses of technology. We also interviewed two administrators about their goals for technology use at Woodvale and conducted three student focus group sessions to learn how students perceived the influence of the laptops in their lives.

In the second year of the study, participant observation produced data from a variety of settings. From November to May we observed each of the three target teachers at least twice a week for 16 weeks. Each of the three teacher cases was also "shadowed" throughout the school day for approximately three weeks during the middle of the school year. The activities in which teachers participated and their actions in those settings were recorded in field notes. On numerous occasions, our spontaneous discussions with teachers were reconstructed and recorded.

Analytic Methods

Data analysis was iterative and consisted of reading the transcribed or archival documents, coding them, comparing and contrasting emerging themes, and attempting to devise more inclusive themes (Miles & Huberman, 1994; Strauss & Corbin, 1990). From data collected in the first phase we drew on sociocultural theory to focus on several aspects of the environment. The first was the concept of teacher beliefs and how they manifested them-

selves within the institutional culture to bear on the use of technology in teaching. Relevant aspects of those beliefs related to participants' perceptions of the school's mission, the broader purposes of schooling, the reasons that their students chose the school, the responsibilities of teachers, and finally, the role that technology could play in teaching and learning. The second concept was that of "settings," in which the teachers could share or access ideas related to teaching with technology. We operationalized settings as the immediate social situations within which learning can occur, marked by the specificities of time, place, participants, goals, and motivations. We identified several such settings within and outside the school. We created data tables for each participant that listed settings to which they had access, how they participated in these settings, and evidence for how they constructed, with others, ideas about the use of technology in teaching.

Finally, to give an account of how participants' practices with technology changed, we departed from our emic perspective and used a "closed categorical system" to describe the trajectory of participants' technology use over the course of two years. We adapted from Becker and Ravitz (1999) a list of five elements that characterized constructivist classrooms and used this as an index to describe changes in instruction and technology use. The characteristics are (a) having students engage in collaborative group projects in which skills are taught and practiced in context, (b) designing activities around teacher and student interests rather than in response to an externally mandated curriculum, (c) focusing instruction on students' understandings of complex ideas rather than on definitions and facts, (d) teaching students to assess their own understandings, and (e) engaging in learning in front of students rather than presenting oneself as fully knowledgeable.

Findings

The selection of Carol, Stephan, and Julia proved to be fortuitous. Their choices about how to use technology in their classrooms emerged from different personal histories, unique ways in which they reconciled perceived institutional expectations for teaching with their own beliefs about students and learning, and varying access to settings in which one could learn about technology.

In Part 1 of this section we explore how these individuals' personal histories as teachers and their beliefs about students and learning played out in the context of the institutional culture to influence their thinking about technology use in the classroom. This section includes a summary of the changes over time in participants' uses of laptop computers and overall pedagogical orientations. In Part 2 we describe the various settings for learning about technology in which these individuals participated, and we hypothesize about how they constructed images of technology use for themselves as a result of participation in those settings.

Part 1: Instructional Choices About Laptop Integration: The Interplay of Teacher Beliefs and Institutional Expectations

Carol—Background and Beliefs

Eighteen sixth-graders file into Carol Peters's social studies classroom. The students gradually find their places at desks arranged in clusters of three or four and pull their laptops out of their cases. "Boot up!" Carol announces. Students pick up on their work from the day before on a multimedia presentation of a hypothetical trip down the Nile River. Some students use wireless modems to access images of the Great Pyramids of Giza and audio files of Egyptian music from the Web. For the duration of the class, they busy themselves with finding, sharing, and embedding these files into their presentation software as Carol patrols the room offering help to those who ask for it.

Carol Peters is a White woman in her mid-forties who arrived at Woodvale with 10 years of experience in both public and private secondary schools. Before being hired full time to teach seventh-grade social studies and language arts, she was a substitute teacher at Woodvale for two years and during that time enrolled her son there as a fifth-grader. Carol was impressed with the image of community projected by the Woodvale students, parents, and staff. She saw the faculty as unified in purpose, focused on academic achievement, and committed to the students. She also knew that if she encountered a classroom problem or had a question about how to work with parents, she could rely on her colleagues for assistance. She identified "an institutional memory that seems to be alive and well and is passed along by all the building's teachers—the more senior teachers."

Carol's positive image of the school community was due in part to the parents' involvement and their desire for high academic standards. The faculty knew most parents on a first-name basis, and many parents felt comfortable walking "right into the classroom to see what's going on." Communication between home and school, as well as academic achievement, Carol believed, were two areas of concern on which parents placed a great deal of emphasis. She stated that "most of the parents expect to be notified immediately if a student hasn't turned in work or if a student's acting up or whatever." Often, parent-teacher conversations centered on the parents' aspirations for their children, or more specifically, on how parents could help prepare their children to achieve the test scores needed for acceptance into select private high schools. "So in that respect," Carol observed, "it's a lot different, certainly, than my teaching in public schools."

Carol believed that the school's administration had confidence in the teachers' skills and gave them great latitude in crafting their own curriculums. In developing learning experiences that could challenge her students, Carol had to draw on her own professional knowledge and on contributions from colleagues:

Each one of us is responsible for designing our curriculum. We're given a set of textbooks that I think you could certainly change if you

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wanted, but that's it. . . . There's a lot of influence from the people around you and we're working hard to try and collaboratively teach as much as possible.

Carol worked closely with Woodvale's experienced teachers to learn which aspects of the curriculum were emphasized and which aspects were open to interpretation and adaptation.

When Carol first came to Woodvale, she did not think the challenges were "any different than in any other school. You have typical teacher responsibilities—teaching as well as maintaining order, and keeping on top of kids to make sure that everyone gets their work in." Carol had believed that learning was best achieved in a traditional setting, characterized by students' quiet attentiveness to the teacher and the use of uniform, skill-based activities for all learners. Soon after arriving at Woodvale, however, Carol began to question some of the assessments that she had used to measure what was being learned. She experienced growing dissatisfaction with her use of multiple choice tests and the students' steady diet of drill and practice. Eventually, because of the smaller class sizes and her perception of a general absence of discipline problems at Woodvale, Carol decided to suspend her preoccupation with classroom order and began to experiment with group work and project-based activities.

Carol's willingness to make these changes was predicated, in large part, on her beliefs about students. When she compared her current middle school students to those with whom she had previously worked, Carol described the Woodvale students as "kids of privilege, a lot of travel, a lot of opportunities available to them. The kids are very comfortable in talking with most of the teachers. . . . There's not a lot of fear or anxiety about dealing with adults here, which is really neat." Carol acknowledged that her students' mature attitudes toward adults contributed to changes she was undergoing in how she thought about her role as a teacher and in her movement toward more student-centered instruction.

Carol's Use of Laptop Computers

Carol's reconsideration of her pedagogy was coincident with the introduction of the laptops at Woodvale. She saw connections between the affordances of the technology and the needs of her students as developing adolescents. To Carol the laptops represented an age-appropriate "hook" akin to the information-rich encyclopedias that had captured her own imagination as a child. Perhaps more important, Carol also associated the laptop's appeal with the students' hunger for using and manipulating "adult level information." Middle school students, she reasoned, "are trying on different adult hats, coats, pants, to see what fits." The capability of laptops to combine access to information (through the Internet) with the use of authentic digital tools to develop professional-looking products was enough to convince Carol that the laptop had a role to play in her classroom.

Despite the decision to incorporate laptops into her teaching, Carol felt she had little institutional support for learning how to do so: "[Woodvale] gave me a laptop and a classroom. . . . There has been no, 'This is how you can go about integrating this into your curriculum.' I've been left on my own to do it." Still, she was committed to moving from didactic instructional approaches toward more student-centered, project-based lessons and was undeterred by the prospect of figuring out how to take advantage of the laptop.

What made the process of learning how to use the laptop so challenging, according to Carol, was conceiving of the intersection between the technology, the curriculum, and classroom management without "knowing what a laptop-equipped classroom looked like." Carol's first chore when she developed laptop lessons was to inspect the software itself and learn about its features before she attempted to have her students use it: "I was not ready to have them do PowerPoint presentations until I understood how to make it work myself. And once I learned how to make it work, then I understood the possibilities of how I could apply it in different places." She also realized that students were just beginning to learn how to access and organize electronic information; she believed it was her responsibility to help students learn how to use the software in addition to learning the intellectual skills that represented her goals of instruction.

After Carol began implementing projects and group work, she recognized significant modifications in her practice that were associated with student laptop use. She noted changes in her instructional relationships with students ("I circulate and offer encouragement or correction or guidance"; "I don't stand up and lecture the way that I used to"; "Oftentimes, I'm finding that they're teaching me, too, which is really cool"), changes in how she dealt with a more active classroom ("My tolerance of them not being completely silent has changed as well"; "It's not as important to me to worry about whether they're quiet—it's whether they're engaged"), and changes in her mental model of productive classroom activity ("The laptop makes them more independent, because it focuses their attention on what they're doing, not what I'm doing all the time"; "How can I get them to learn about that by going out and finding the information for themselves and creating a product of some sort?").

The changes in Carol's classroom, however, were neither immediate nor unproblematic. For example, to facilitate the desired group interactions, Carol arranged the classroom desks into six groups of three. Occasionally, that setup prompted too many unfocused conversations during class time. Carol eventually asserted her authority and rearranged the desks back into rows. When students were asked to work in groups, the portability of the laptops allowed them to gather around individual desks. Three months later, however, the desks were moved back into groups because Carol was "growing tired of the clutter that was part of the row arrangement." With rows she was finding it difficult to move between the backpacks and laptop cases strewn around students' desks. In addition to the room arrangement problems, Carol and her students found the wireless modems to be too slow to

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access the Internet on many days. And because each room had only eight modems, Carol frequently had to borrow extras from other teachers. Despite these inconveniences, Carol persisted throughout the year in her efforts to integrate technology into her teaching.

Over the course of the first year with the laptops, a transfer of responsibility for learning—from the teacher to the students—was under way. Carol observed, "They are looking to their own sources of information for the answers to questions rather than constantly coming to me." She believed that students who engaged in her laptop-facilitated projects were "being forced to [use] a lot of the higher-level thinking skills a lot more often, applying what they've learned." She viewed the laptop as a means for her students to accommodate their individual learning needs and for her to orchestrate classroom learning experiences that had been impossible before the laptops. Carol was convinced that it was her own willingness to re-envision her role and identity as a teacher that ultimately contributed to her ability to use the laptop for student learning.

Carol's Summary Changes in Teaching Practice

Over the two-year period of observation, Carol's classroom culture became more constructivist along several dimensions. Although Carol used group work with her social studies class at the beginning of the study, she then extended group work into her language arts curriculum and began to use projects in both classes as a way for students to learn content and skills in context (element 1 of this study's constructivist framework). The language arts class still relied on her use of the textbook; however, students began to use CD-ROMs and the Web more often to locate information and create presentations to share with others. Carol selected project topics in both social studies and language arts classes, but by Year 2 she was allowing students to explore their own specific areas within those topics and giving them more latitude in the resources they could use as well as in the format of final products (element 2). At the beginning of the study, Carol had a pre-existing focus on students' achieving complex understandings of the subject matter in addition to knowing basic definitions and facts (element 3). But over the two years, Carol had become skilled at orchestrating projects that prompted students to build more sophisticated ideas around a topic. For example, she designed a technology-supported project in which students explored the sociology of smokers and smoking; by contrast, versions of that topic taught in previous years had focused solely on physical issues related to smoking. Over time, Carol also began to include opportunities for her students to reflect on their own thinking processes during class discussions (element 4). She was comfortable about revealing her own thought processes as well and about letting students know when she was in a position to learn (element 5). Carol was originally reluctant to reveal her knowledge deficits in technology—she wanted a sense of control over how technology was talked about and used in the classroom. Her discomfort in revealing unfamiliarity with technology

diminished over time but did not entirely disappear. Overall, by the end of Year 2, Carol was using the laptop almost daily in language arts and social studies. Moreover, elements of constructivist teaching were thoroughly integrated with her various uses of technology.

Stephan—Background and Beliefs

Stephan Gonzales is finishing an e-mail message at a desktop work station in the back of his classroom. Nearby is a table with professional mathematics journals, newsletters, and a copy of the state standards. At the bell, his students come into the room and go immediately to their assigned groups of desks with three or four classmates and read their assignment from the board. Some students know they will need a calculator to solve today's problem or a small whiteboard to "represent their thinking" (as Stephan says) and go to the closets to get what they will need. Students begin concentrated work within their groups, knowing that at the end of class, Stephan may ask any one of them to explain their thinking about the problem. One group of students is finished early, and Stephan tells them to get out their laptops, access the Math Forum website, and work on the Problem of the Week posted there.

Stephan Gonzales is a Latino man in his late thirties who teaches eighth-grade algebra and seventh-grade mathematics at Woodvale. During his 14-year teaching career, he has taught mathematics primarily in private secondary schools. Stephan's first experience at Woodvale was being hired halfway into the school year in order to co-teach mathematics with a struggling first-year instructor. Despite the conditions under which he was hired, he looked at it as an opportunity to establish himself in a new setting. Stephan noted that organizational life at Woodvale functioned differently from what he experienced at other schools. He observed, "I don't perceive myself in a hierarchy here, where I have more so in other schools. I see myself as part of the middle school group or team, including [the principal]." Within the middle school, Stephan's collegial network was unique. As a homeroom teacher he maintained close connections with the other seventh-grade faculty, and because he taught algebra to all of the eighth-grade students, he had regular contact with all eighth-grade teachers as well.

Stephan sensed a strong parental presence at Woodvale. To him it was a constant reminder of how parents' involvement in both the affairs of the school and the lives of their children influenced Woodvale's organizational life. Despite high parental expectations for children and teachers, Stephan found his students "sensitive," "honest," and "cooperative," as well as "focused," "independent," and "privileged." However, he detected few academic differences between the Woodvale students and those from less-affluent communities where he had previously taught: "The first time I made the shift from a less-privileged school to a more-privileged school, I thought there would be this dramatic difference among the kids. I didn't notice it then, and I don't notice it here, either, in terms of day-to-day, how they interact with each

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other, how they do math." Stephan maintained a strong belief that all his students at Woodvale possessed the mathematical abilities to achieve at a high level.

During Year 1 of the study Stephan began to reflect on his own pedagogy; in particular, he questioned whether his students were actually learning mathematics concepts or just memorizing algorithms associated with problem solving. He wrestled with what it meant "to know" in mathematics. To explore these questions further, Stephan decided to enroll in a master's program at a nearby university and soon encountered an instructor who used a constructivist approach to teaching. He came to appreciate the importance of student-to-student dialogue in small groups, establishing meaningful relationships between ideas, and the role of metacognition in learning.

As he was rethinking his approach to teaching mathematics, Stephan decided to exercise the curricular autonomy afforded the Woodvale teachers. In the spring of Year 1 he attended a National Council of Teachers of Mathematics conference, where he acquainted himself with the College Preparatory Mathematics (CPM) curriculum. The following summer he attended a workshop on CPM, and in Year 2 he piloted the curriculum with his students. He described his new perspective:

I'm more likely to approach math . . . in more of a research context. Like getting them to do some sort of research at whatever level. Let's examine a question. Let's spend a month figuring out what this means, gathering information. Whereas before, maybe I didn't appreciate the value of it as much.

Over time, Stephan realized that this curriculum was more compatible with his evolving conceptions about how algebra ought to be learned.

Stephan's Use of Laptop Computers

As Stephan was implementing the new algebra curriculum in Year 2 he was also contemplating the schoolwide impact of the laptop program. Stephan had used calculators and desktop computers in his previous classroom settings but had not experienced the variety of tools and the information access capabilities of the newer-model laptops. He noticed that his students were "very focused on the laptop as a tool or a learning device, which isn't the case with other learning devices," but he was not convinced about the positive impact of computers in his mathematics classroom. He said, "I've seen desktop computers brought into learning environments and gauged the effect, and . . . found the effects to be minimal."

Despite his pessimistic approach toward laptops, he said that "if the tool is going to be there, I want it to make life easier for me and for them." Stephan wanted to capitalize on students' inherent interest in technology by creating Web-based learning activities that were as "visual and jazzy as possible." He found several Web-based learning exercises and used them occasionally with

his seventh-grade students. This was done early in Year 1, before he had begun his university coursework, and, in line with his more traditional pedagogical thinking at the time, he identified websites that provided additional drill and practice for students who finished individual seatwork early.

Later in Year 1, Stephan designed a Web-based companion course for his eighth-grade algebra students and planned a small number of lessons on the use of other mathematics websites for enrichment and review purposes. He further considered digitizing his lesson worksheets and activities for students to complete with their laptops to make his own life "a lot easier," but eventually relied instead on hard-copy materials packaged with his curriculum.

Stephan attempted one technology-supported, project-based unit in mathematics during Year 1, in which students used the sinking of the Titanic as a context for finding and solving problems. Stephan immediately confronted an unaddressed issue regarding assessment. He was accustomed to employing objective means to measure his students' performance, but when he discovered some of the challenges associated with assessing students' technology-based projects, he realized the complexities associated with new ways of teaching: "It's just more difficult. It's more subjective, and it [assessment] becomes very ongoing." This realization ultimately lowered his expectations for the use of the laptop in his classroom.

Stephan also saw his colleagues struggling with the laptops in their classes. In Stephan's view, the teachers at Woodvale who experienced success with laptops (such as Carol) had to hurdle substantial obstacles to integrate them successfully into their curriculums. And because the laptop required changes in classroom management, teachers had to think about instruction differently as students began to assume more control of their learning.

In Year 2, Stephan began to take a more constructivist approach to teaching by allowing his students to work collaboratively on complex problems in class; however, he rarely integrated laptops into this instruction. Even though Stephan still did not use the laptops in his mathematics teaching, he saw that his students frequently used their laptops during a morning homeroom period as they prepared for their other classes. He noticed how the social dynamics of his room shifted when students worked with their laptops. He observed that when the laptops were in use, students were less inclined to label their peers based on academic achievement. They began to think about each other in more inclusive ways: "They know who is the expert at doing different things, so they seek each other out for expertise. I think it changes sometimes who the resource people are."

Despite witnessing collaboration and positive social dynamics during his homeroom periods, Stephan did not feel that he was prepared to use laptops in his mathematics classroom. He expressed concern that, at the outset of the laptop initiative, not enough thought went into programmatic issues such as how technology could be used in mathematics, language arts, or science. Mathematics teachers from other laptop schools also began to express

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their concerns through an electronic discussion list to which Stephan subscribed. He confided, "I'm starting to discover that other schools that are starting the [laptop] program are having similar difficulties, thinking, 'Now, how will this go into math?' " Not wanting to dismiss outright the value of the technology, he said that the contributions of the laptop were primarily in the area of professional productivity. "Right now, I feel the technology is being most helpful to me in planning next year. . . . For what I'm teaching for math, I don't think it's that valuable."

Finally, Stephan was concerned about being pressured to use the laptops, even when they did not seem suitable to play a role in his teaching:

But then you start to feel like, well, this may not even be better than without the (laptop), you know what I'm saying? So, I'm not going to abandon what I think the school wants me to do with math just to incorporate technology. "Here's the laptop. You have to use it." I haven't gotten *that* message, but I wonder as the program develops. . . . I wonder if that won't start happening.

Stephan's Summary Changes in Teaching Practice

Over the two-year period of the study, Stephan made significant shifts toward constructivist instruction, many of which centered around his use of the new mathematics curriculum. In Year 1 Stephan had students work in groups only occasionally and attempted one laptop project with his students but found the assessment for it too complicated and subjective. He taught with a traditional curriculum using a combination of worksheets and textbook problems. By contrast, in Year 2 Stephan focused on a smaller number of ideas taught through the use of richly contextualized problems. Students worked collaboratively on those problems almost every day (element 1 of this study's constructivist framework). The curriculum, however, did not reflect the interests of the teacher or the students (element 2). Stephan's intellectual demands on the students also shifted over time. For example, in Year 1 the emphasis of his classes was mostly on computational skills and drill and practice; his instruction was geared toward "right answers." By Year 2 Stephan was teaching the concepts and skills in the context of more complex problem solving (element 3). Students were allowed to use calculators and routinely used whiteboards in small groups to "represent their thinking" to others. Whereas in Year 1 students were rarely asked to assess their own understanding of mathematics concepts, in Year 2 they were asked to verbalize their problem-solving strategies during class and to reflect on them (element 4). In Year 1 Stephan was not observed engaging in learning in front of students. In Year 2 he occasionally demonstrated his thinking processes as he attempted to solve math problems but did not often portray himself as a learner to his students (element 5). Use of computers in his classroom during both years of the study was restricted to occasional enrichment work on websites by individual students.

Julia—Background and Beliefs

Julia Waters is seated on a stool behind a table as her sixth-graders fill in the rows of seats in front of her. To begin class, Julia directs her students' attention to a question about yesterday's language arts lesson written on the board and asks them to quietly do a 15-minute "free-write" using their laptops. Most of her students have left their laptops in the lockers and need to ask permission to retrieve them. Later, after students are finished, Julia leads a brief discussion of their responses. Students' laptops are then stowed under their desks for the remainder of the class period.

Julia is a White woman in her late forties. A lengthy experience as a part-time art specialist in her children's K-8 Catholic school led her to pursue a teaching credential about 10 years before the study. Later, during Julia's multiple pre-service internships, she was placed primarily in urban public school settings. These varied but brief experiences led her to conclude that it was unrealistic for her to "bring [the students] to a high level of academic achievement" during the time she was with them. She attributed the academic success of some of her students to their "natural talent" and believed that those students were predisposed to do better in school than other students. Upon receiving her certification, Julia's preference was to teach in a public school setting, where she believed she could focus on meeting the educational needs of underserved and underrepresented students.

Despite her intention to work in public schools, Julia began as a seventh- and eighth-grade teacher at a parochial school and taught there for two years before coming to Woodvale during the second year of the research study. Still relatively new to teaching multiple subjects, she was asked to teach four different classes at Woodvale (sixth-grade language arts, social studies, literature, and seventh-grade language arts). When she learned that her students all would have their own laptop computers, she looked forward to the challenge of learning more about teaching with technology. Although she was familiar with computers, Julia had never used the technology, let alone laptops, in a classroom setting.

One of the differences that Julia noted between Woodvale and previous teaching assignments was the students' more familiar relationships with their teachers. While speaking to her students one day in class about excessive talking, she exclaimed, "I'm not used to students who have as much freedom as you do!" According to Julia, students had "too many privileges." However, she recognized that the maturity of her students could contribute positively to a system of student-led parent conferences, which she advocated and eventually implemented at Woodvale.

After hearing about Woodvale's reputation as a school with extensive parental involvement, Julia was initially cautious when she met with the families of her students. Soon, however, trust replaced caution:

The parents provided assistance and . . . helped me survive in many ways. Field trips and phone calls, and following up and reminding me of things and all the stuff that's kinda related to the day-to-day, of

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the school day, but part of the whole [Woodvale] picture. . . . They've been really, really great.

Julia became genuinely pleased with the role the parents occupied in the school, and her relationships with the parents became "more positive here than I've experienced anywhere." She began to feel respected for her professionalism and sensed that parents appreciated, in particular, her use of the state academic standards to guide her teaching.

Julia's identity as a professional appeared to be tied to her beliefs about the importance of standards. She felt that at Woodvale she was "the only one who knows anything about the [state standards]." Julia believed that private schools should "absolutely" pay attention to standards and participate in the state's assessment system for public schools. It was her belief that Woodvale's lack of a standardized curriculum was also problematic. "In a public school, they do it. You know, 'This is what we're all doing. We're all working toward this.' There's a lot of consistency." With regard to curriculum development, Julia felt that teachers at Woodvale had "too much autonomy." She was encouraged then, when the Head of School convened a faculty committee to begin a process of schoolwide curriculum alignment, but was later disappointed in her colleagues for what she perceived as reluctance on their part to embrace the proposed changes.

Julia's beliefs about standardization and consistency were reflected in her teaching as well. She associated optimal learning with order and compliance, but implementing classroom management strategies to maintain those conditions occupied a considerable proportion of her instructional time. Her repeated attempts to set and enforce behavioral guidelines met with mixed success. At midyear she introduced a classroom behavioral contract and required her students to sign it before posting it on the bulletin board. The decorum of her classes, however, remained largely unchanged.

Julia's Use of Laptop Computers

Since arriving at Woodvale Julia had found that, for her, part of the new and challenging teaching context was the technology. Her first encounter with technology at Woodvale was the summer workshop (held between Years 1 and 2) on how to support student projects using the laptop's tools. Julia came away from the workshop firmly believing that teaching with technology was the norm at Woodvale. Despite her unfamiliarity with the classroom use of computers, Julia started her first school year by creating a Web-based map skills project in social studies. With their laptops, her students used special Internet sites to "travel" around the world in hypothetical hot air balloons and then used global coordinates to navigate from one destination to another. She asked her students to do background research on the Internet to find the cruising speed of hot air balloons, then calculate the distance and time it would take to travel between, for example, two of the seven wonders of the world. In addition to learning map skills, she intended that her students experience an interdisciplinary project requiring them to use "multiple

intelligences" in its execution. The details of the project required considerable time for her students to understand, and assessing the projects became complicated and subjective. But when the unit was concluded, Julia recalled, her students were "really motivated."

Soon, however, despite students' enthusiasm for her initial project, this type of classroom activity became less frequent. Julia stopped developing her own projects, and as several opportunities arose for her to use projects developed by her colleagues, she chose to implement only limited subsets of a few of them with her own students. As the year progressed, Julia began to question various aspects of the use of technology at Woodvale. For example, she was aware of students' projects in other classes and saw several examples of multimedia presentations that they had created, but she felt that the presentation software was ultimately a distraction from learning:

I think it's a presentation tool rather than an assessment or a learning tool. So, if your goal is to present something to a group and that's an essential part of what you're doing, then I think they're good to use. But if your goal is to show what you've learned and know through some sort of final project . . . I think it's a glitzy tool that isn't necessary, and sometimes I think is too time consuming.

To add to her doubts about the usefulness of technology, Julia began to question how frequently her colleagues were using laptops with their students. "I heard you don't use them in your other classes," she told her students one day and then gave them her rationale for why they would not be using laptops more often in her own classes. There were also other "signs" that Julia interpreted as an institutional rethinking of laptops. She observed,

We give "free dress" days to kids so they don't have to wear their uniforms. That's a treat. That's a gift. We also give free "no-laptop" days. That's a treat. To me, if that's an intrinsic type of reward that we build into a positive day or a kid-friendly day, to say "no laptops," then to me the idea of having these portable laptops to carry around isn't necessarily something that they're excited about.

According to Julia, the presence of the laptops affected the students and the classroom environment in a number of ways. She perceived that many students were gratified by how the laptops provided them with immediate access to information; for some students, she believed, the ability to produce professional-looking documents by using word-processing software contributed to improvement in their self-esteem. She also thought the laptops contributed to positive changes in how students interacted with one another during project work. However, the use of the technology was often a problem. Julia felt that the laptop interrupted the "flow of the day," and she thought that her room was too small to facilitate efficient laptop use because there were too few electrical outlets. The laptops were often precariously balanced on students' desks with power cords looping away into a confusing tangle on the

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floor. As students moved around the room, they had to navigate by stepping through or jumping over the mess. She explained her reluctance to make laptops part of the classroom environment: "I see that they're oftentimes distracted by their use because they're shuffling things around. It's another something to deal with. To open, to close. To worry about, to keep track of cords."

In addition to her perception that laptops generated classroom chaos, Julia experienced uncertainty about when to use the laptops and what to use them for. She had little time to learn more about technology. Julia's planning time was consumed with preparations for four different classes, and she gradually acquiesced to the demands of her workload, becoming less concerned with learning how to use the laptop. She eventually integrated laptops into her teaching primarily through word-processing activities in which every student used the laptop at the same time to complete highly prescribed tasks.

In an interview at the end of her first year, Julia offered metaphors for the laptop that revealed a limited view of its role in teaching and learning. She stated, "I guess, at this point, I think of implementing the laptops like I would, pretty much a pen or pencil." She mentioned, however, that she would not allow her students to use the laptops for some writing assignments because she thought they needed "to keep in touch with their writing. . . . It's going to be done in cursive and it's going to be done in pen." She also identified a number of unresolved issues as reasons to reject "portability" as an argument for adopting laptops. These included laptop damage due to dropping or misuse and the potential for students to hurt themselves by carrying around the extra weight. Portability, she said, was probably important only to the "ten percent who view [the laptop] as their personal tool that's important to have, in terms of their own to keep."

Julia's Summary Changes in Teaching Practice

Despite the fact that one of her first teaching activities (the hot air balloon project) employed several constructivist dimensions, she returned to more teacher-centered approaches for the remainder of her first school year and the beginning of the next. No more group or project-based strategies were employed throughout the year or into the first quarter of the following year (element 1 of this study's constructivist framework). Julia entered Woodvale with a preference for externally mandated curriculums and recognized standards as an important part of "what is taught and how it gets taught." At the beginning of her second year, she acknowledged the value of project-based strategies but believed their implementation was in the realm of more experienced teachers (element 2). Her instructional focus for the duration of the study was on basic skills and rote-level knowledge (element 3). Her students' use of technology exclusively for word processing indicates this instructional conservatism. Although Julia did not ask her students to reflect on their understanding of the subject matter (element 4), she was interested in having students lead their own parent-teacher conferences as a way for them to reflect on and articulate their knowledge. With regard to engaging in learning in front of her students (element 5), there were no examples observed

throughout the study. Julia was especially reluctant to reveal knowledge deficits in situations where technology was used.

Part 2: Participants' Social Dynamics and Their Opportunities to Learn in Various Settings

"Learning About" Versus "Learning How" Settings

Although classroom technology use appeared to be influenced by individual participants' institutionally situated beliefs about learners and learning, much of what they learned took place in the context of social or professional interactions with others. Interactions that Woodvale faculty had with colleagues, students, and parents about the use of technology were not simply occasions for "acquiring bits" of information about the use of laptops in teaching. Data suggest that many of those interactions were influential in the creation or revision of mental models for the role of technology in teaching, and some interactions served to realign technology-related norms and expectations of participants with those of other actors in the environment. Those interactions were situated in *settings* that were characterized by the specificities of time, place, participants, goals, and motivations. Settings for participants in this study included informal hallway conversations, shared lunchroom time, joint planning periods, faculty meetings, technology inservices and workshops, parent-teacher interactions, and laptop conferences. We classified settings in which conversations and activities centered on two broad themes: *learning about* the role that the laptop was expected to play within the institution and *learning how* to use laptops in the classroom. Although all settings contained elements of both "learning about" and "learning how," we made inferences about whether each setting foregrounded "learning about" (norms and expectations for laptop use at Woodvale) or "learning how" (to use the technology in the classrooms).

"Learning about" (LA) settings were characterized by *institutional voices*. Those settings included faculty meetings, parent meetings, and regional laptop "summits" with faculty from other schools. LA settings served a key organizational function at Woodvale because they were occasions for transmitting, negotiating, and contextualizing school norms and expectations. As teachers participated in those settings they learned about Woodvale's institutional priorities and performance expectations and ultimately constructed for themselves a range of uses for the technology that was proper and possible in that context.

Faculty meetings were the primary LA settings in which the prevailing philosophy of the school was made explicit and reinforced. During Year 1 of the laptop program, the school's Director of Technology used the opening 20 minutes of faculty meetings to discuss applications of the laptop for classroom use, new productivity tools for teachers, or emerging technical problems. Teachers were also asked to demonstrate the use of software applications to colleagues. The Director of Technology's agenda occupied this time at faculty meetings until midyear, when, to the disappointment of the faculty, he resigned due to personal conflicts with the Head of School.

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A technology support person was hired as a replacement but was not given an administrative position. By February of Year 1, the future of Woodvale as a laptop school depended largely on the teachers and on how well they could learn to use the technology in the absence of an expressly conceived professional development plan.

A second type of LA setting, those in which parent-teacher interactions took place, served to reinforce expectations for the use of technology from the broader school community. These interactions took the form of after-school visits from parents, parent-teacher conferences, and parent information meetings. In one such meeting, parents of fifth-graders were invited to discuss with the faculty their children's transition from the elementary school to the middle school. The meeting began with staff introductions and brief presentations by teachers. Attention then shifted to several middle school students and the multimedia demonstrations of project work that they had completed with their laptops. After the student presentations, many parents wanted to know more about laptop use. One parent asked how these types of assignments were graded. A language arts teacher explained that rubrics were constructed so that students could be "graded on content, not all glitz." She explained further that "[t]he laptop doesn't drive the curriculum. We use it when we need to. . . . We can do more inquiry-based learning with the laptop. . . . The laptop facilitates problem solving." Parents continued to probe the teachers with critical questions about laptops in the middle school; however, no parent appeared unsupportive of its use. The purpose of the evening meeting was to discuss a host of issues about the children's transitions from elementary to middle school; however, in that setting, the faculty witnessed parents' persistent interest in the laptops.

Whereas faculty meetings and interactions with parents conveyed a mixture of messages to teachers regarding the school community's expectations for the use of technology, an LA setting outside the school itself—a laptop educational conference—gave several teachers another perspective on Woodvale's commitment to technology. During the first year of Woodvale's program, Carol attended a national conference with some of her colleagues. Prior to attending the conference, the Woodvale teachers felt that there was an institutional commitment to the laptop program and a vision for its place in the school. What several teachers discovered when they attended the conference was that they needed much more infrastructure and leadership. Carol related what she had learned:

They call it a "summit" because it's a gathering of schools that have laptops in place and schools that are considering laptop programs. . . . We went in thinking that we were really doing a good job at integrating the laptops into the classroom. And we are. But the biggest problem is that we're doing it without a lot of the support mechanisms in place that we need, and we didn't know we needed them, and now we feel like we're really out on a limb. . . . I don't think [the Middle School Director] was quite prepared for what we came back ready to say, which was that in order to make this work the way it

needs to work, the way we all would like to have it work, the level of commitment needs to be ratcheted up considerably.

The Woodvale teachers returned from this conference and shared with colleagues their new understanding of the school's limited curricular support for technology, informed by reports of what was happening in other laptop schools.

In contrast to the institutional voices of LA settings, *learning how* (LH) settings were characterized by *conversational voices* about technology and socially negotiated norms for its use in classrooms. Compared to LA settings, where the broader context of school life and community bracketed references to the laptop, participation in LH settings focused on teachers' more immediate concerns about using laptops in specific classroom situations. And whereas LA settings were generally public, LH settings included not only public conversations but other types of interactions among small groups of teachers or between a teacher and her or his students. This meant that each teacher could participate in various combinations of LH settings, allowing varied trajectories for learning about the laptop and its use in the classroom. LH settings included professional development workshops, informal small-group conversations in hallways, shared planning periods among teachers, lunch periods, and the participants' classrooms.

One public LH setting was a two-day workshop held during the summer before Year 2 of the study. A nationally recognized "laptop curriculum expert" guided the Woodvale teachers through explorations of multimedia presentation software, spreadsheets, and word-processing tools. During the workshop the teachers created multimedia products that included digital images and audio and video files downloaded from the Web. The presenter walked the teachers through a model of a student research project that emphasized "identifying, searching for, harvesting, organizing, and presenting information." The dual focus of the workshop was on what *students* could do with the tools and how learner-centered uses of technology required new ways of thinking about teaching (emphasizing project-based learning, capitalizing on student interests, negotiating rubrics with students, etc.). Carol, Stephan, and Julia all attended the workshop and, as will be discussed later, appropriated different ideas to apply to their own practice.

In contrast to this publicly shared workshop environment, most LH settings were characterized by casual social interactions. Because Carol, Stephan, and Julia moved in different social orbits at the school and participated in different LH settings outside school, the particular combinations of interactions that these three teachers had with others in connection with the use of laptops shaped their own use of the technology in significant ways.

Carol's Participation in LH Settings

Carol's easy relations with her colleagues and her growing reputation at Woodvale as a user of technology drew her into daily conversations with peers about the "big" and "little" ideas of using computers. In one typically

informal exchange, Carol stopped to visit with a colleague in her classroom before school. As they were talking, Stephan walked into the room to say hello and to announce that he had "finally found a math website worth using." It was a trigonometry site that he was intending to use with his seventh-graders. Carol asked him for the Internet address so she could investigate the site with her ninth-grade daughter, and five minutes later Stephan returned with a printout from the site. Carol was involved in such interactions several times each day and often continued conversations with other teachers by e-mail in the evenings.

Carol also participated in a more involved and ongoing LH setting with Joan, a close colleague with whom she shared planning periods. Joan was developing her own constructivist ideas about instruction, and she reinforced Carol's growing propensity toward student-centered teaching. They also shared an interest in using technology. During their joint planning periods they co-constructed projects for their students, critiqued one another's use of technology, and developed between themselves a shared image of student-centered teaching. Carol and Joan also signed up together for on-line technology courses offered by a local university. Over time, Carol and Joan jointly crafted increasingly sophisticated project-based activities that incorporated collaborative work and invoked higher-level student thinking. Their work together culminated in a presentation at a regional laptop educators' conference during Year 2 of the study, in which they chronicled their efforts to use technology at Woodvale. They chose "Clueless in Seattle" as the title and hoped that their story would offer guidance to others who found themselves in similar positions. They wanted administrators to heed the message "Take it slowly and adjust to teachers' needs."

As Carol experimented with student-centered activities, she witnessed transformations in her classroom environment that were precipitated by the technology. Her classroom became a proving ground where she could not only test the affordances and constraints of the technology in the context of her lesson designs but also see how far her students could take the technology by themselves. Thus Carol's classroom became one of the most potent settings for learning how to use the laptops. Her first hurdle was to overcome concerns about having an "active" classroom:

Having them work together on the computers, . . . the—my—model of "you must sit in your seat and be quiet" has gone completely out the window. I've become a lot more tolerant of the noise. . . . Generally, even when they're noisy and they're moving around—they're moving around for a purpose.

Developing a tolerance for activity allowed Carol to see her students using new kinds of thinking, exhibiting independence, and participating in new social dynamics:

I think it's, by doing more of the project-based learning, they're being forced to do a lot of the higher-level thinking skills a lot more often,

applying what they've learned. They're answering their own questions more often than they used to and I think they see, they have the information resource right there. And so I think that they don't view research, even to just answer simple questions, as such a task anymore. It's okay. "I need a picture of bridges." That was one of the things that came up this morning in class, and I had three kids trying to find a picture of bridges. They went to Encarta, then they went to my Encarta, and then they went on the Web. They never did find the picture, but [laughs] that's okay. They were looking. . . . And I think that that's not the kind of thing you would've seen. The three kids that were looking were *not* the kids that needed the picture.

Carol tempered her enthusiasm, however, with a realistic appraisal of her students' "research" sources:

I think in one way it's been something of a detriment, because they are relying on the Web and relying on Encarta an awful lot, and both of those can be really shallow sources. I can remember at their age going to an encyclopedia and getting stuck, because I liked to look through the pictures and look at the articles, and they're not doing that as much anymore. What they are getting off the Web tends to not be very in-depth.

Despite this, Carol was cautiously optimistic about the substantive effect of laptops on the work done by her students:

I think it extends the school day, because they're taking these projects home. . . . I think that a lot of the technology appeals, is visually appealing to them, which I would say is something that's very important to them. At times they seem to not care so much about content as they do about that visual appeal. But what I'm finding is that they don't see the end of the page as often. If you tell them, I want an essay and I want it four pages long, if it had been handwritten, they got to the bottom of that fourth page, and that was it. And I don't see that very often anymore.

Stephan's Participation in LH Settings

Stephan's thinking about teaching and technology appeared to be influenced by his involvement in three settings—informal interactions with his peers, university coursework, and the classroom. As described earlier, Stephan was considered a confidant of many of his Woodvale colleagues, and he participated in dozens of informal conversations with peers each week. Of the exchanges that related to technology, most were brief and centered around "tips and tricks" with technology (finding interesting websites, identifying new software functions). He was not as invested as Carol was in discussing new ways to use technology in the classroom; rather, he wanted to share information about websites that would be of general interest to other teachers or that his students could use for enrichment exercises.

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As mentioned earlier, Stephan's philosophy of teaching underwent a major revision between Years 1 and 2 as a result of his participation in a setting that was not related to the use of technology—a university course that focused on student motivation and was taught using constructivist principles of instruction. As a result, he made plans to enact his vision of constructivist instruction within the framework of his recently adopted curriculum model (CPM), which emphasized deeper student understanding of a smaller number of key mathematics ideas and a spiral curriculum approach. He gave students problems to solve in groups, allowed them to work with calculators, and encouraged them to use whiteboards as tools to make their thinking explicit to one another. Students' thinking processes became as much a focus of attention as getting the right answer.

During this time of change, Stephan did not see how the laptops could contribute to this new vision of student learning. Consequently, the laptops did not make any regular appearances in his mathematics classroom, although he did use technology extensively as a productivity tool for himself. Despite Stephan's lack of classroom use of the laptops, he noticed how students used the technology during his homeroom period when they were free to prepare for the day. His mathematics classroom, then, was not an LH setting for Stephan, but his homeroom period was. He noted students' inherent interest in the technology, its effects in drawing them together, and their new mindset about using laptops for tasks that were not originally designed to require their use:

With the laptop, they just kind of gravitate toward it, if that makes sense. I do see them being more collaborative. And again, it's a very automatic thing. I don't even think they're aware of it. But if two people pop open a laptop and they're working on the same thing, it's almost automatic that there'll be some exchange of "How are you going to do it?"; "How did you do this?"; "How did you do that?" You don't even have to put them in groups. They just come together. I think they're, I think they feel more in charge. . . . Like in homeroom, you'll suggest, well here's something I want to do, here's my objective, and you won't introduce it necessarily as a laptop lesson, and they'll go, "Oh, can we do it this way?" They have ideas of how they can use Word or Excel or PowerPoint or whatever to carry things out, rather than wait for you to tell them do it this way—they have their own way.

Stephan was particularly fascinated by the new kinds of classroom social dynamics that the technology engendered:

Well, what I said before about them collaborating; it's funny. One thing I remember reading in the literature when we were doing training, people having concerns about them (computers) isolating students, and that I'm not observing at all. You know, one student just on his own. It just rarely happens. There's always some sort of need for another perspective. . . . The technology requires interaction with

another a lot of times. Let's see, what else? They've become, they know who is expert at doing different things, so they seek each other out for expertise . . . it does change the classroom management atmosphere significantly.

Despite his positive assessment of the social effects of laptop use, his own extensive use of the technology for professional productivity, and his shift toward constructivist approaches to teaching, Stephan did not further integrate the laptops into his mathematics teaching through the end of Year 2 and into the following fall.

Julia's Participation in LH Settings

In contrast to Carol's participation in a variety of LH settings and Stephan's easy social networking among colleagues, Julia operated in relative isolation. Her first interaction with teachers at Woodvale was the technology workshop given the summer before Year 2 of the study. This was an LA as well as an LH setting for Julia, where she likely sensed the institutional expectations to use technology in the classroom. At the workshop Julia was not included in many conversations, nor was she introduced to her peers. It portended for her a school year of polite but distant relations with colleagues. Throughout the year Julia rarely collaborated with other teachers during shared planning time, and she was rarely part of the casual hallway small talk in which other teachers passed along, among other things, ideas about using the laptops. A few times she exchanged information about interesting websites with other teachers, but those occasions did not generate more substantive discussions about using the technology. Julia had little conversational access to peers that could foster her thinking about teaching or the use of technology.

In Julia's first month of teaching, her classroom started out as a potentially rich LH setting in which she could understand more about using the laptop and see where students took the technology. Julia said that she had "just thought up" the hot air balloon project as an interesting way for students to learn mapping skills. By several measures, this was a constructivist use of the technology, involving complex problem-solving, collaboration among students, multiple paths to success, and a role for the teacher as a facilitator of student thinking. Julia quickly became aware that her students were technology-proficient and that they understood project-based work:

And I guess I would say there's a few things that different teachers have said, this is a good thing to use with the laptop . . . PowerPoint presentations. The kids knew how to do them. So all I had to say was "This is what your project needs to be" and give parameters around that. But I don't have to teach it—I couldn't. They knew how to do it.

In the end, however, Julia felt that the project consumed too much time and that assessing the students' work was too difficult. Compounding her reluctance about using the technology, she also began to suspect that other teach-

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ers were not using the laptops as much as she had believed, and over the next few months she refocused her planning energies on "standardizing the curriculum" rather than dealing with the laptops. To Julia, standardizing the curriculum included homogenizing the learning experiences of the students. For the remainder of the school year, Julia's desire for order and compliance in her classroom precluded the use of laptops for projects or other activities in which there was not a quiet work atmosphere and a uniformity of learning experience across all students. As a consequence, the classroom withered as an LH setting. Julia was unable to witness or learn from her own students' uses of the technology in the context of self-regulated learning or collaborative work.

Despite her reluctance to use technology, late in her first year Julia agreed to represent Woodvale at a national laptop conference.³ She participated in several sessions at the conference in which various speakers touted a new vision of classroom learning through the use of technology and the requisite shifting of teachers' roles. When she returned from the conference she appeared to have reassessed her stance on the use of the laptops:

I didn't think anything differently until I went to that [conference]. And then I realized that it would be very fun for the kids if I could create more problem-based learning activities. So they're going to learn by solving a particular problem which involves finding and constructing information using the laptop. . . . I guess I learned that if we want to use technology to its maximum potential as a classroom tool and a teaching aid or enhancer or whatever, then developing lessons looks different when you're using technology.

Also late in her first year at Woodvale, Julia had submitted a proposal to a local foundation's teacher leadership project and was excited to learn that she had been awarded a substantial grant to spend on classroom technology.⁴ We were interested to see how the conference experience and new grant would affect Julia's use of the laptops, and we returned to her classroom in the fall following Year 2. One of her first purchases had been a portable projector, which she was using to display the day's lessons from her laptop. In addition to the projector, Julia had purchased a color printer, digital cameras, a scanner, and a desktop computer. Despite the windfall, students had not used any of the new hardware, nor had they been using their laptops. Julia explained that for the second year in a row, she was faced with four preparations each day. She cited her busy schedule as a reason for maintaining her teacher-directed instructional strategies.

Discussion

Our findings indicate that the influence of ubiquitous technology on instructional decisions was mediated in substantial ways by teachers' interrelated belief systems about learners in that particular school, about what constituted "good teaching" in the context of the institutional culture, and about the role of technology itself in the lives of students.

The laptop program at Woodvale started just as Carol was rethinking her own instructional philosophy, questioning her teacher-centered approaches and the value to students of an exclusive diet of basic-skills work. Moreover, she understood that the faculty members at Woodvale had wide-ranging freedoms to change their approaches to instruction to help learners meet the high academic expectations expressed within the school community. The small class sizes and Carol's absence of discipline concerns were also enabling conditions for her to begin experiments with constructivist instruction. Although those conditions laid the groundwork for her new designs for teaching, it was her beliefs about the students that furnished connections between prospects of a learner-centered classroom and the use of technology. Carol understood that her students came from privileged backgrounds, but she chose to think of them as maturing adolescents who were exploring adult identities. Conceptualizing her students in that way, Carol saw the laptop as a gateway for them to a world of information shared by adults and as a set of tools enabling her students to create professional-looking products. And as she began to adopt more learner-centered strategies, the laptops brought changes to her classroom. The software tools and access to the Internet enabled a constructivist atmosphere to take hold. Students could work collaboratively on complex projects as Carol removed herself as the hub of authoritative discourse and adopted a role as co-learner with the students. The laptop as an "agent of change" was evident in her thinking. Among her claims, for example, were that "the laptop makes them [the students] more independent because it focuses their attention on what they're doing, not on what I'm doing all the time," and that "the laptop extends the school day" (allowing students to bring the tools and resources of the classroom home with them).

Stephan's story was similar to Carol's in several ways. He felt that his students were motivated and capable, and he believed that they could all learn mathematics. He, too, began to question the effectiveness of his teaching and was concerned about whether his students were constructing a deep knowledge of mathematics concepts or simply memorizing algorithms. And, like Carol, Stephan capitalized on the autonomy afforded him at Woodvale to adopt a new curriculum that was more compatible with his evolving conceptions of how mathematics could be learned.

For Stephan, however, laptops were not necessary tools for the empowerment of his students. It was not his beliefs about students but rather his beliefs about what counted as legitimate learning activities in a mathematics classroom that influenced his choices about using laptops. In Year 1 of the study, Stephan's conception of mathematics learning involved the sequential mastery of basic skills, applying those skills to solve problems posed by the teacher, and arriving at right answers. He had difficulty imagining how laptops could play a role to support that kind of learning; technology did not seem necessary in a classroom oriented toward prescribed problem sets and convergence on discrete answers. Instead, Stephan was focused on the ways in which he could use the laptop for his own professional productivity and

to increase the efficiency of his work by digitizing the curriculum for students. Stephan's image of teaching was challenged in Year 2 by his participation in a university course in motivation. His emphasis on what counted as mathematics learning shifted from an exclusive emphasis on right answers to having students think deeply about concepts and problems. His classroom changed dramatically as he allowed students to work in groups, engage in more complex problems, and explain their thinking to one another; but he maintained that the laptop's various software tools and connections with the Internet were of little use in this new classroom environment. Even though he had adopted a strong curriculum and his thinking about mathematics learning had taken a "constructivist turn," his classroom remained centered on teacher-constructed problems and sequential attainment of concepts, which continued to shape his views of the usefulness of technology.

Julia, like Carol and Stephan, believed that students at Woodvale were privileged. To Julia, however, "privileged" meant that the students had too many freedoms. Whereas Carol saw the small class sizes and the lack of behavior problems at Woodvale as the right conditions in which to give more adult-level tasks to her students, Julia seemed threatened by student liberties in her classroom. Her views on classroom order did not reflect a sense of confidence in students' ability to work collaboratively. Equally disturbing to Julia was her perception of the "loose" curricular approaches of her colleagues. In response to her beliefs that standards were being ignored by most faculty at Woodvale and that students had too much license in classrooms, she became invested in standardizing the curriculum of various subjects, homogenizing the learning experiences of the students, and maintaining a teacher-centered classroom. She was reinforced in these efforts by the notion that parents had come to respect her for her professionalism, which was linked in her mind to a strict standards-based approach to teaching.

As the participant who knew the least about technology, Julia held the most simplified image of the laptop. She considered it "a presentation tool rather than a learning tool" and in some situations no more than "a pen or pencil." She also dismissed the notion that students appreciated owning their laptops, projecting that it was only important to the "ten percent who view [the laptop] as their personal tool that's important to have, in terms of their own to keep." In contrast to Carol, who viewed the laptop as a tool for knowledge construction and a gateway to the world of adult ideas, Julia had marginalized every aspect of the laptop: from the use of it in her classroom to her image of it as a tool, to her perception of how students felt about owning one. Although it is difficult to ascertain whether these beliefs constrained her use of the laptops or whether she legitimated her limited technology use by expressing such views, it appears that, to a degree, both were true.

In putting Julia's beliefs into perspective with her work environment, we cannot overlook the teaching load as a factor contributing to her instructional conservatism. The pressure to prepare for four classes each day undoubtedly influenced her ability to create activities that used technology. Her work load did not appear, however, to be the sole reason for her choosing not to

use technology. Carol and other colleagues had designed several technology-supported social studies projects and had shared them with Julia. Julia, however, used only small "pieces" of some of the ready-made projects and chose not to use most of those offered to her.

As the three participants made decisions about the use of technology in their classrooms, they appeared to assess the potential for the technology to create learning conditions that (a) were congruent with their beliefs about learners and their needs, (b) were consistent with images of "what counted" as learning activities in specific subject matter areas, and/or (c) allowed control over the learning environment to be placed in the hands of the students or the teacher (depending on the instructional philosophy). Although all of these were likely to have influenced participants' thinking about the use of technology, Carol appeared to frame her decisions primarily on the basis of her beliefs about learners' needs; Stephan, by the nature of the subject matter; and Julia, by a desire for classroom control.

What claims can be made, then, about the relationship between ubiquitous technology and constructivist instruction? The technology *did not initiate* teachers' movements toward constructivist pedagogy. For Carol, who had a pre-existing dissatisfaction with her teacher-centered classroom and believed that her students could be independent learners, the laptops were catalyzing agents that made collaborative and project-based student work possible. For Stephan, movement toward constructivist pedagogy was preceded by dissatisfaction with his earlier approach to teaching, initiated by his participation in a university class that modeled constructivist principles of instruction, and made possible by his introduction to a new curriculum that supported teaching for understanding. The technology, however, did not play an evident role in the transformation of his teaching. For Julia as well, the availability of ubiquitous technology was not an influence on her pedagogy. She did not see how the laptops could enhance her traditional approach to teaching. She was never conflicted about her instructional philosophy or her limited use of technology.

In addition to examining the interplay of teachers' situated belief systems and their use of technology, we discovered a number of settings in which participants learned about technology use from peers, administrators, teachers in other laptop programs, and outside experts and from their own students. For example, in various LA and LH settings, Carol constructed an image of Woodvale's expectations for technology use and learned more about how to use laptops in classroom situations. She initially felt strong institutional support for the use of technology; however, when the Director of Technology left, the school technology talk was not as explicitly supported through formal channels but rather was sustained through a network of informal social interactions among faculty. She felt, as did others, that she was on her own. That sense was reinforced by her participation in the national laptop conference, where stories about the curricular support needed to sustain technology use in schools made Woodvale's efforts seem inadequate. Despite Carol's perceptions from various LA settings that the institutional support was lack-

ing, she continued to learn in various LH settings about specific uses for technology in the classroom. Carol's classroom itself eventually became an LH setting in which she learned what her students were capable of and how technology fit in with her new vision of instruction. Also, her regular social access to colleagues helped her to picture how others were using the technology and how successful they were. Her joint lesson planning with Joan was a particularly powerful LH setting because with Joan she could have continuing conversations about how technology could be used in the context of constructivist teaching. Their equal-status relationship (both were new to the technology and to constructivist practice) appeared to be as fruitful as a relationship in which one is mentored by a more knowledgeable other.

Stephan, on the other hand, did not see the value of laptops in his mathematics classroom, even though he saw his students demonstrating competence and positive social dynamics in connection with the use of technology during homeroom period every morning. In this setting he witnessed his students' fascination with the technology, their tendency to collaborate spontaneously, and modest changes in classroom dynamics when students who were usually out of the social mainstream became sought-after "technology experts"—observations that are consistent with those reported in other studies of technology-rich classrooms (Podmore, 1991; Schofield, 1995; Shrock & Stepp, 1991). Stephan also participated in regular informal conversations about technology. But his frequent interactions with colleagues and observations of students did not lead him to use technology for mathematics instruction. After two years and a dramatic change in instructional philosophy, Stephan held firmly to his view of the laptop as a productivity tool—for himself.

Some settings were designed to help participants learn how to use the laptops, but those settings also conveyed institutional messages about the importance of technology. For example, Julia's first experience at Woodvale was the laptop workshop held a few days before the start of school. The workshop was primarily an LH setting for the returning Woodvale teachers, but Julia likely perceived it as an indicator of the importance placed by the Woodvale community on teaching with technology. As a novice to technology, Julia began the year with a project-based unit that incorporated the use of the laptops. Soon, however, as she observed the other teachers, she realized that the use of technology was not the norm she had been led to believe it was at Woodvale. From that point, Julia's use of technology dropped precipitously and shifted to become more consistent with her beliefs about control in the classroom (employing only teacher-directed word processing, for example). In turn, the classroom became a limited LH setting for Julia to learn more about students' capabilities with laptops. Julia's estrangement from the faculty also restricted her opportunities to participate in the informal LH settings that took place as conversations in hallways or in classrooms before school. She was removed from almost every opportunity to learn more about technology in teaching. Julia fit the definition of a "private practice teacher"—

socially and intellectually isolated from her peers. Riel and Becker (2000) found that only 4% of the 1,800 private practice teachers in their study were highly active computer users and that private practice teachers tended to engage in teacher-centered instruction.

Summarizing the observations of teachers in various settings, it appears that settings cannot be unproblematically construed as "opportunities for teachers to learn." Settings are not imbued with unambiguous meaning or messages that participants unproblematically appropriate. Rather, participants actively filter what is said and done in these situations through a system of beliefs and actively construct meaning from the circumstances in which they find themselves.

In building an explanatory framework for the evolving practices of the three participants, we have focused on the interplay between teachers' beliefs, institutional context, and teachers' interactions with students, peers, and others in connection with the use of technology. However, we must also acknowledge other factors known to contribute to teachers' effective use of technology, such as administrative leadership, access to models of teaching with technology, and technological infrastructure (Means & Olson, 1996). While the institutional vision for technology use at Woodvale could be considered weak by ideal standards, the administration did offer technology workshops and conference opportunities for all teachers, even after the departure of the Director of Technology. If a coherent vision for technology use had been clearly articulated and if sustained emphasis had been placed on the use of technology by the administration, it is arguable that Julia and Stephan might have felt more compelled to integrate laptops into their teaching. The same could be said with regard to the availability of models for teaching with technology. It is possible that greater exposure to practices of effective computer-using peers could have prompted Stephan and Julia to experiment more with technology. Julia and Stephan, however, maintained internally persuasive rationales for not using the technology that may have made them less than receptive to modeling efforts by others. Carol, on the other hand, seemed to progress pedagogically without observing any exemplary models. Rather, with her colleague Joan, she co-constructed increasingly sophisticated learning activities with the laptops. With regard to the question of infrastructure, the school was wired for networking; every student and teacher had the same set of technological tools, and there was reasonable access to the Internet. While we acknowledge that teachers have varying "thresholds of inconvenience" when it comes to using technology, Woodvale's conditions were highly favorable compared with those in most schools today. Therefore, lack of infrastructure does not seem to be a primary explanatory factor in this study.

In summary, the three participants were subject to the same conditions of infrastructure, administrative support, and exposure to models of pedagogy and yet had very different outcomes with regard to technology. Although such conditions are important for the successful integration of technology into teaching, this study has demonstrated that there are other powerful influences at work in shaping teachers' practices with technology over time.

Finally, although we did not originally intend to address the question of whether pervasive laptop technology, as opposed to desktop technology, created unique learning situations, we found some evidence to that effect. In focus group conversations, Woodvale students uniformly acknowledged a sense of pride in having their own computers, despite the inconvenience of carrying them to class and the cost of purchasing them. In addition, they reported that they were more organized because most of their schoolwork was stored on the laptops. Also, during classroom observations of a number of teachers, we noted that when students were given the opportunity to work with peers they would often reconfigure themselves into "learning cells" of two or more individuals. They would bring their laptops together to work jointly on a product or to share digital information resources (the sheer volume of which could create powerful learning opportunities or bothersome distractions). The membership of these cells could shift as students migrated to other groups to seek help, show off works in progress, offer resources, or socialize. The importance of proximity to others in a computing environment was noted by Schofield (1995) in her study of classrooms with desktop computers. She noted that students had difficulty sharing and comparing ideas or seeking help from others unless the computers were placed close to one another.

Altogether, the laptop computers brought several observable changes in the students' lives and in the school environment. The ultimate impact of those changes on learning, however, could not be determined in this study.

Conclusion

This study provides a window on the working lives of three teachers who struggled to learn and make decisions about integrating technology into their instruction. As we constructed their stories, there emerged three themes that explained a great deal about how and why teachers change (or do not change) their technology-related instructional practices over time.

First, the influence of ubiquitous technology on instructional decisions was mediated in substantial ways by teachers' interconnected belief systems about learners in that particular school, about what constituted good teaching within the context of the institutional culture, and about the role of the technology in the lives of students. Those belief systems influenced participants' conceptions of what was proper and possible in their classrooms. Teachers imagined the affordances and constraints of technology and indexed them against the potential for the technology to create learning conditions that were congruent with their beliefs about learners and their needs, were consistent with images of what counted as legitimate learning activities in specific subject areas, and/or allowed control over the learning environment to be placed in the hands of the students or the teacher.

Second, the condition of pervasive portable technology did not initiate teachers' movement toward constructivist instruction. The availability of technology was neither a necessary nor a sufficient condition to affect pedagogy—

indeed, the fact that all students had their own computers did not compel two of the participants to use the technology itself to any significant degree in their classrooms. In one important case, however, the laptops were catalysts that enabled a participant, who had a pre-existing dissatisfaction with teacher-centered pedagogy and rote-level learning, to transform her classroom through experimentation with collaborative student work and project-based learning. A second participant who had similar dissatisfactions with his teacher-centered strategies began to implement constructivist elements into his instruction over time but never conceived of how laptops could substantially support the kinds of thinking and classroom activities associated with his new vision of mathematics learning. A third teacher, who was comfortable with basic-skills and teacher-centered approaches to learning, devalued the potential impact of the technology and perceived it as a distraction.

Finally, norms and expectations for technology use were generated through a number of activities within the school community but were reinterpreted by individuals through participation in a variety of settings, some of them outside the school. Clearly, one of the most powerful settings is regular planning time with a colleague who shares both an interest in technology and a desire to advance in pedagogy. The fruits of such collaborations can then be tested in classrooms where teachers can see how children use technology in planned and unplanned ways for productive purposes, what conditions enable children to be autonomous learners with technology, and how the role of the teacher must necessarily shift when technological resources and technology-competent students are present. Taken as a whole, settings were sense-making opportunities for participants to construct meaning in connection with the use of technology. Yet the collective impact of participation in those settings appeared to be dramatically shaped by teachers' situated beliefs about learners and legitimate learning activities in the classroom.

These findings have implications that are relevant to efforts to introduce laptop computers into schools. For example, there can be no individual or institutional "vision of technology use" that exists separately from beliefs about learners, beliefs about what characterizes meaningful learning, and beliefs about the role of the teacher within the vision. Before commitments are made to introduce technology on the scale of "laptops for everyone," members of the school community must hold public conversations to reveal such beliefs about learners and learning and to make explicit the ways in which technology might facilitate progress toward shared goals based on those beliefs. Similarly, professional development opportunities should not focus exclusively on skills with computers. Rather, technology use should be more thoughtfully considered within the context of teachers' beliefs about what constitutes effective teaching and how technology and information access can alter the traditional roles of teachers and students in the classroom. Only within that context does it make sense to identify and explore specific applications of laptops for instructional use. Development opportunities, furthermore, should include subject-specific conversations about how modes

of inquiry in the various disciplines can be supported with technology. In addition to these professional development efforts, it is important to have consistent work time with colleagues who share a desire to advance their teaching while exploring the use of technology in the classroom. Such relationships, in conjunction with professional development opportunities, may play a key role in sustaining growth in instructional sophistication and technology use. Conversely, the conditions of professional isolation and minimal preparation time during the school day virtually assure that teachers will not make fundamental advances in their instruction or experiment with technology.

This study has demonstrated how complex the picture of technology integration is within our schools. Developmental models of technology use that emphasize the simple accumulation of computer-related knowledge by teachers via workshops and in-services underestimate the powerful influences of (a) institutional expectations for technology use; (b) teachers' beliefs about learners and learning, which are mediated by the specific character of the school community; and (c) the host of informal ways in which teachers learn to use technology. As the wave of laptop initiatives spreads throughout the country, ubiquitous personal computing in classrooms is becoming a reality in many schools. It is arguable that the universal use of portable computers by students in schools is inevitable. With it comes the need to better understand how that trend affects the lives of teachers as well as the character of institutions, and the need to make informed recommendations that will allow good teaching to flourish—with or without technology.

Notes

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¹ "Constructivist instruction" and "student-centered teaching" are interrelated but not synonymous concepts, and each has contested meanings (see Nola, 1997, and Chung & Walsh, 2000). Teaching that allows students to use their own interests as one of the bases of classroom activities, that encourages productive student-student dialogue in the quest of meaning-making, and that supports the collaborative development of unique products that are evidence of understanding will be considered both student-centered and constructivist in this research report. Project-based learning, which can also take various forms, generally invokes learning conditions that are considered constructivist.

² Laptop programs in schools can differ along several dimensions. In some programs, every child in a school has his or her own computer. In others, only students in selected classrooms have laptop computers; and in still more modest programs, limited numbers of laptops are kept on carts and used in classrooms as needed. Who receives the technology is often tied to who pays for it. Some programs are funded almost entirely by grants, and students' families are not required to purchase the requisite hardware and software. Other programs require students' families to make significant financial commitments by purchasing the computers themselves—a sum that commonly exceeds \$2,000 per child. In the most comprehensive laptop programs, all students in a school or grade level own their own computers, bringing them to every class each day and taking them home each evening.

³ Julia was asked to attend the conference by the Middle School Director, who felt it would be beneficial for her to see how other teachers were using laptop technology in their classrooms.

¹ Julia had been encouraged to apply for the grant by the Head of School, with whom she had developed a close professional relationship. Julia's proposal was for a number of technology peripherals (digital camera, projector, printers, etc.) that would enable her students to make broader use of their laptops in creating learning products.

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